THE EFFECT ON SURFACE FUELS AND FIRE BEHAVIOR OF THINNING A *PINUS PINASTER* STAND IN CENTRAL PORTUGAL

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ABSTRACT

It is normally assumed that thinning a forest stand can change the characteristics of surface fuels and, therefore, change the behavior of a fire occurring in those conditions. In order to assess this changes we have performed a fuel inventory for three different thinning situations. The treatments were: no thinning, removal of 15 percent of the trees, removal of 30 percent of the trees. The results showed no significant differences among the different treatments for most of the different fuel categories. Nevertheless herbaceous cover seemed to be negatively correlated with tree density. Accordingly to these results we also were not able to find any significant differences concerning fire behavior characteristics.

Keywords: fuel treatment, fire behavior, thinning, *Pinus pinaster*, Portugal

INTRODUCTION

The overstory layer of a forest stand strongly affects surface fuels, both directly and indirectly. This is caused by the amount of radiation that is allowed to reach the ground but also because of changes in wind speed which may affect fuel moisture (Guyot, G. 1990). Solar radiation has a direct effect on the understory since it influences the growth of heliophyte herbs and shrubs which are frequently a major component of forest fuels in Mediterranean conditions (Dreyfus, P. 1990). Silvicultural treatments influencing tree canopy cover such as thinning, may therefore play an important role on understory development (Montgolfier, J. de 1989). On the other hand thinning itself increases fuel load since it increases the amount of slash and litter on the ground. Since these two major effects have a direct influence on fire behavior, it seems reasonable to assume that the management of forest fuels to reduce fire hazard can be done by controlling thinning intensity. Several studies have demonstrated a fire severity increase due to the accumulation of slash from thinning operations (Kalabokidis, K. and Wakimoto, R. 1992; Kalabokidis, K and Omi, P. 1998). Nevertheless none of these studies was performed in Mediterranean regions, where the shrub component is of crucial importance.

METHODOLOGY

In order to study these effects in the medium term, we have used a set of plots that were established in 1993 and whose initial purpose was to assess the effect of thinning on tree growth. The study area is a 22 years old State owned maritime pine (*Pinus pinaster*) forest, located about 30km East from Coimbra (Central Portugal).

The experimental design consisted on a set of two treatments plus one control plot, with two replications. The two treatments consisted on removing 15 (moderate thinning) and 30 percent (heavy thinning) of all trees within a plot. Understory vegetation was cut before the thinning operation which took place in 1994. The main understory species occurring were *Calluna vulgaris*, *Chamaespartium tridentatum*, *Ulex* sp. and *Pteridium aquilinum*. Given the small dimensions of the trees, all the material cut was left on-site. In July of 1998 fuels were inventoried in all plots using the planar intersect technique for slash and a destructive sampling for the remaining fuels (Van Wagner, C. 1968; Brown, J. 1974). On each plot (40 x 40 meters) three transects 30 m long were laid-out as a randomly oriented triangle, in order to estimate the total slash load. Shrubs and herbaceous plants were collected within a 1 x 1 meter quadrat to determine fuel load by size class and condition (Burgan, R. and Rothermel, R. 1984). A similar procedure was adopted for litter at the same sampling location but using a 0.5 x 0.5 meter quadrat. For each transect we have chosen two different locations for destructive sampling, in order to obtain the most representative spot in terms of vegetation characteristics. For each sample we separated the different fuel categories and determined their dry weights. Percent cover of herbaceous plants, shrubs and slash was calculated by averaging the respective intercepted lengths.

Using both field and published data we were able to build a fuel model for each plot using the program NEWMDL (Burgan, R. and Rothermel, R. 1984) from the BEHAVE package. This same system was used to simulate surface fire behavior for typical summer conditions: 6% fuel moisture for 10 and 100 hr fuels, 100% fuel moisture for herbaceous and shrub live vegetation, and 10 $km.hr^{-1}$ for midflame wind speed. Extinction moisture was set to 40% and the fire behavior predictions were adjusted according to observations during experimental fires (Fernandes, P. data on file). Additionally, we have separately estimated 1hr fuel moisture for each plot with the MOISTURE module from the FIRE2 program of BEHAVE, to take into account the effect of different tree densities, and simulated the respective fire behavior.

Analysis of variance was performed to test the existence of significant differences between fuel characteristics and between fire behavior in the studied situations.

RESULTS

Fuels

Fuel results are displayed in Table 1. When comparing the different treatments only percent cover of slash and percent cover of herbaceous vegetation proved to be significantly different (P=0.040 and P=0.038, respectively). When plotted against tree density (see Figure 1), herbaceous cover showed a significative

Fuel Characteristics	Control	15 %	30 %
Total litter load	2.9±0.3	2.6±0.2	3.2±0.5
1 hr litter load	2.6±0.1	2.3±0.1	2.9±0.4
Herbaceous load	0.2±0.1	0.3±0.2	0.2±0.1
Herb. % cover *	6.0±3.0	14.5±2.5	22.5±1.5
Shrub load	0.9±0.0	1.1±0.3	1.0±0.2
Shrub % cover	11.9±1.0	17.2±2.4	11.8±3.1
Slash load	1.6±0.8	4.7±0.3	3.9±1.7
Slash % cover *	2.0±0.0	5.5±0.5	6.0±1.0
Total 1hr load	2.9±0.2	2.7±0.3	2.9±0.3

Table 1. Results for fuel characteristics (mean±SE). All loadings are in $ton.ha^{-1}$. Significant (P<0.05) differences between treatments are indicated with *.

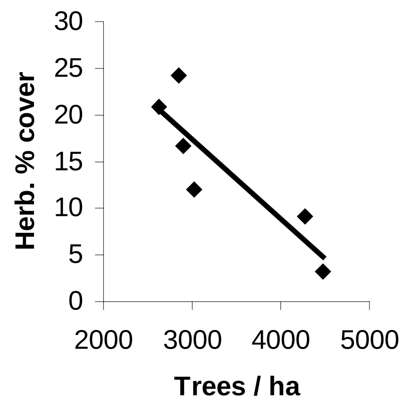

Figure 1. Relation between herbaceous cover and tree density.
(P=0.0189) negative correlation with a determination coefficient of 0.78.

Fire behavior

Results of the fire behavior simulations are displayed in Table 2. Moisture content for 1 hr fuels was calculated using MOISTURE program.

Fire behavior	Control	15%	30%
R	8.6±1.3	5.8±0.9	7.5±1.3
H_A	7181±161	7275±914	8173±1359
I	1032±180	717±198	1056±342
L	1.9±0.2	1.6±0.2	1.9±0.3

Table 2. Results for fire behavior (mean±SE).
R - Rate of spread (m/min), H_A - Heat per unit area (kJ/m²), I - Fireline intensity (kW/m), L - Flame length (m)

Comparison of the means by analysis of variance showed no significant differences for all the fire behavior parameters. This same result was obtained when using a constant value of 6% for 1 hr fuel moisture content.

DISCUSSION AND CONCLUSIONS

Our results basically indicate that, under this study's conditions, neither the canopy cover reduction nor the slash input caused by thinning had, in the medium term, a significant effect on surface fuels and, consequently, on fire behavior. In terms of fuel characteristics, the increase of herbaceous and slash cover with thinning intensity, although ecologically significant, does not seem to have important consequences in terms of fire behavior. Several interpretations can be made in order to explain this results.

The first thing to be pointed out is the reduced number of replications available which may have precluded more conclusive results. In general, fuel load presents a higher variability than percent cover, which have allowed, in this latter case, to obtain significant differences in the analysis of variance. The different sampling approach used for these two parameters but also the different nature of the two variables should explain these differences of data dispersion.

Nevertheless, despite the limitations of this study, we may conclude that the widespread idea that a more open stand should lead to an important development of the shrub understory (Montgolfier, J. de 1989) for Mediterranean conditions, does not seem to be a general rule, even if we have to account for the fact that the understory vegetation was reduced before the thinning operation. Both shrub cover and shrub load present quite similar values for the three situations. On the other hand that same generalized idea seems to be applicable to herbs and ferns, especially *Pteridium aquilinum*, which tends to cover more open areas.

In what concerns the other fuel categories the occurrence of similar values for total load of 1 hr time-lag fuels is remarkable. That can be easily understood if we note that most of this load is coming from the litter layer, mostly constituted by pine needles. It seems that during the four year period between the thinning treatment and the fuel inventory, litter contribution from the standing trees plus litter contribution from the fallen trees was about the same for the three studied situations. Different results would probably have been obtained if fuel inventory had been performed shortly after the thinning operation.

This similarities in fuel loading and in the overall fuel-complex structure explain the lack of differences in the fire behavior descriptors. The introduction of different values of 1hr fuel moisture for the different canopy cover situations did not change this results.
Future studies should address fuel changes immediately after the thinning operation in order to monitor the evolution of the different fuel categories for different thinning situations.

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